Before The
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In The Matter Of Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems	)))))	ET Docket No. 98-153

COMMENTS OF RF METRICS CORPORATION ON REPORT
OF THE STAFF OF THE OFFICE OF ENGINEERING AND TECHNOLOGY
PROJECT 02-02

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Summary

The Federal Communications Commission report titled "MEASURED EMISSIONS DATA FOR USE IN EVALUATING THE ULTRA-WIDEBAND (UWB) EMISSIONS LIMITS IN THE FREQUENCY BANDS USED BY THE GLOBAL POSITIONING SYSTEM (GPS)" released on 22 October 2002 does not provide a sufficient description of the measurement system nor of the measurement technique to allow an independent analysis of the measurement results. Moreover, a limited analysis using the information that is given in the report indicates two problems with the measurements:

1. Many of the measurement results do not agree with the stated measurement system performance parameters.
2. The system as described in the report suffers from a significant vulnerability that could produce spurious emissions within the system itself. Some measurements show potential evidence of such spurious emissions.

Unfortunately, measurements that are typically collected to resolve these issues were not reported. It is the opinion of RF Metrics Corporation that these inconsistencies coupled with a lack of explanatory information are enough to render the measurement results inconclusive. This prevents their use in drawing conclusions regarding the ambient noise environment at the measurement locations until such time as these issues are resolved.

Introduction

The Federal Communications Commission has produced a report containing ambient radio emission measurements made at 7 outdoor sites and 8 indoor sites. The system used to make the measurements was designed to make very sensitive measurements of both noise-like and signal-like emissions. It is based on a spectrum analyzer as the power measurement device, to which low-noise amplifiers and an antenna have been attached. The system was operated in a swept mode using RMS averaging across the GPS bands containing L1, L2, and L5 as well as a portion of the Aeronautical Radio Navigation Band from 960 – 1160 MHz.

1.1 The measurement system's performance is not adequately described, nor is the measured data consistent with the limited description that is given.

The two systems used for the measurements are shown in Figure 1. The increased sensitivity required for noise measurements is achieved by cascading two low-noise amplifiers (LNA's) in front of an Agilent E4440a signal analyzer. To protect the system from non-linear behavior in the presence of strong signals outside of the measurement bands, a tunable bandpass filter has been placed between the antenna and the first LNA. The system performance parameters for the individual components in the system are summarized in Table 1.

Using these performance parameters, a cascaded gain and noise figure analysis neglecting cable losses results in a system noise figure of 4.3 dB for system A, 6.1 dB for system B, and system gains (excluding the antenna) of 59 dB and 56 dB respectively. These values differ significantly from the measured system gains of 65-67 dB and 64-66 dB respectively. The reported gains of the individual components and the calculated noise figures are detailed in Appendix A.

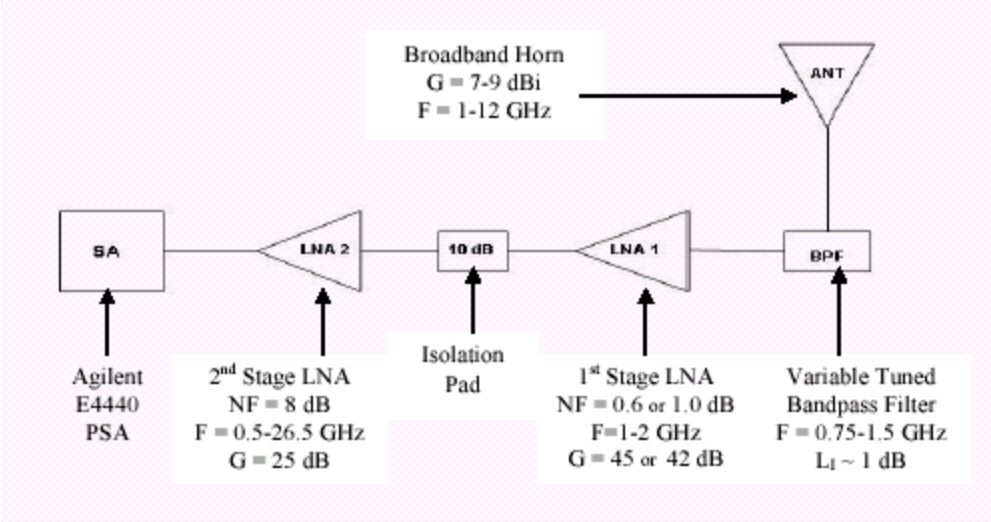


Figure 1. Reported FAA Measurement System.

Commentary

A noise figure characterization is not reported for the system as a whole nor is a measured gain and noise figure reported for any of the individual system components. Therefore it is impossible to independently determine the system noise floor. All of the claims in the report regarding broadband ambient noise in the measurements are based on an implicit assumption of the system noise floor that is never stated nor measured. As a result there is no way to separate the ambient noise contributions from the system noise contributions in the reported data.

The report offers no justification for the choice of a system design that includes both 65 dB of gain and 50 dB of attenuation in the signal path. However, an analysis of the cascaded dynamic range shows that the HP83017A LNA is particularly vulnerable to intermodulation and gain compression in the reported design. For system A, a calculation shows that the system will incur 1dB of gain compression at input signal levels from –51 dBm to –47 dBm. For system B the compression point is between -50 dBm to –46 dBm, depending on frequency[1].

1.2 The processes that produce the ambient noise environment are not adequately characterized by the measurement technique.

The measurement technique used in the report is to collect both an RMS average power across the measured band simultaneously with a maximum power measurement. The Agilent E4440A is configured to use averaging detection, but is *undersampled* by using a sweep time that is too short to produce an RMS sample of adequate variance. This results in a value that is close to a sample-detected response. These values are

[1] For the system as shown in the block diagram with 10 dB of discrete attenuation and 40 dB of attenuation invoked in the HPE4440A.

passed both to a max hold algorithm and a trace-averaging algorithm in the E4440 to produce RMS and max hold traces.

Commentary

This method of collecting noise data does not give an adequate indication of the statistical process being estimated by the measurement. For example, are the features shown in the graphs produced by pulsed emissions from radio navigation services or from emissions that are more noise-like? Furthermore, the classification of trace features as being produced by a narrowband source rather than a wideband or noise source are not supported by this measurement technique.

1.3 The data plots do not separate the contributions of the ambient emissions from system noise. Additionally, they show indications of gain compression and intermodulation products. The classification of certain features in the plots as "narrowband" is likely erroneous.

The data plots are generated from screen captures of the Agilent E4440 Signal Analyzer. A correction factor was entered into the analyzer to account for the gain in the antenna and RF path. This factor is subtracted from the received signal level at the input of the spectrum analyzer so that the displayed trace represents the signal level present at the output of an ideal isotropic antenna for signals that are well above system noise.

Commentary

Due to a lack of detail in the system description, there is no way to determine the relevance of the RMS trace when it appears to show a noise floor. In the cases where the external gain is different from the measured system gain, there is no explanation for the discrepancy apart from a general comment that attenuation was added for several measurements. The point in the signal path at which the attenuation was inserted is not described.

There is a significant variance in the noise floor of the outdoor measurements. For example, Figure C-15 in the report shows a noise floor value that is presumably the system noise of –122 dBm in the average curve. Figure C-36 shows a value of –118. There is no mention of a systematic or component difference between the systems that made these measurements, yet there is no commentary in the report regarding the difference in noise floor.

Using a best-case component performance scenario as described in Appendix A, the antenna-gain-adjusted system noise floor for measurement system A configured with 64.8 dB of gain and 40 dB of attenuation in the spectrum analyzer is -120 dBm in a 1 MHz bandwidth. Two plots (C-15 and C-16) show a noise floor of -122 dBm, while other plots show a noise floor of between -119 to -115 dBm.

Based on a set of component performance values inferred from the system calibration, the Hewlett-Packard HP83017A preamplifier is likely in saturation when a –45 dBm signal is input into system A (see Appendix A, Figure A-3). Compression in the system would be consistent with the variation in noise floor that is shown in many of the plots. This non-linear response could also cause spurious signal generation in the system itself. In figure D-71 of the report the signal emission appears similar to the harmonic of an NTSC broadcast.

A straightforward set of measurements could be made (if they do not exist already) to indicate the absence or existence of non-linear behavior in the system. A set of data taken at all locations with the system input terminated in a 50 Ohm load would be sufficient to indicate the system noise floor as well as indicate the absence or presence of feed-through signals. At sites where there is strong signal activity, an additional measurement with a 10 dB attenuator placed between the antenna and the bandpass filter would be sufficient to indicate the presence or absence of a non-linear system response. These two sets of data would be sufficient to address most of the issues raised in this set of comments.

In Table 6.1 of the report, many of the "narrowband" classifications are erroneous. Since a 1 MHz resolution bandwidth is used in the swept measurements, the system will show a minimum spectral 1 MHz at the 3 dB points for narrowband signals. Most of the features that are identified as narrowband are less that 1 MHz wide. These narrow features are in fact impulsive (wideband) emissions that are large enough in amplitude affect the average.

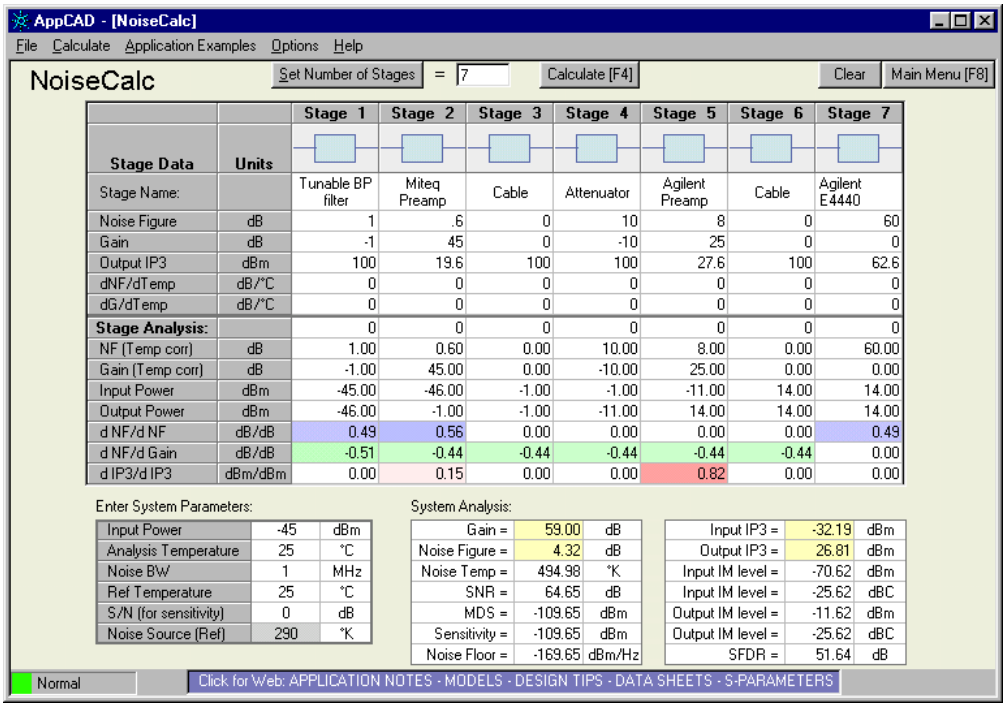
Conclusion

Due to a lack of adequate system description and performance measurements, the data presented in the report are difficult to interpret. The design of the measurement system makes it vulnerable to gain compression and intermodulation products and evidence for both of these effects are present in the data graphs. The nature of the data collection method makes nearly all of the "narrowband" signal classifications invalid.

As a result of these problems, it is our opinion that these results should not be used to justify a rule-making action until these issues are addressed.

Appendix A

The cascaded noise figure, gain, and IP3 values are shown for systems A and B in figures A-1 and A-2 respectively. These values are based on the system performance parameters listed in Table 4-1 of the report. Using the measured system gain and noise figures available from the manufacturers of the components a revised estimate of the system noise figure may be calculated. The cascaded noise figure, gain, and IP3 for both systems are shown in figures A-3 and A-4 based on these revised values. These calculations do not include additional attenuation beyond that described in the report. For System A, the system noise is estimated to vary between –120.1 and –118.7 dBm in 1 MHz, for system B, the estimated noise varies between –177.6 and –119.5 dBm. The frequency dependence of the noise figure for each system is shown in Tables A-1 and A-2.



Stage Data	Units	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7
Stage Name:		Tunable BP filter	Miteq Preamp	Cable	Attenuator	Agilent Preamp	Cable	Agilent E4440
Noise Figure	dB	1	.6	0	10	8	0	60
Gain	dB	-1	45	0	-10	25	0	0
Output IP3	dBm	100	19.6	100	100	27.6	100	62.6
dNF/dTemp	dB/°C	0	0	0	0	0	0	0
dG/dTemp	dB/°C	0	0	0	0	0	0	0
Stage Analysis:		0	0	0	0	0	0	0
NF (Temp corr)	dB	1.00	0.60	0.00	10.00	8.00	0.00	60.00
Gain (Temp corr)	dB	-1.00	45.00	0.00	-10.00	25.00	0.00	0.00
Input Power	dBm	-45.00	-46.00	-1.00	-1.00	-11.00	14.00	14.00
Output Power	dBm	-46.00	-1.00	-1.00	-11.00	14.00	14.00	14.00
d NF/d NF	dB/dB	0.49	0.56	0.00	0.00	0.00	0.00	0.49
d NF/d Gain	dB/dB	-0.51	-0.44	-0.44	-0.44	-0.44	-0.44	0.00
d IP3/d IP3	dBm/dBm	0.00	0.15	0.00	0.00	0.82	0.00	0.00

Input Power	-45	dBm
Analysis Temperature	25	°C
Noise BW	1	MHz
Ref Temperature	25	°C
S/N (for sensitivity)	0	dB
Noise Source (Ref)	290	°K

Gain =	59.00	dB
Noise Figure =	4.32	dB
Noise Temp =	494.98	°K
SNR =	64.65	dB
MDS =	-109.65	dBm
Sensitivity =	-109.65	dBm
Noise Floor =	-169.65	dBm/Hz

Input IP3 =	-32.19	dBm
Output IP3 =	26.81	dBm
Input IM level =	-70.62	dBm
Input IM level =	-25.62	dBC
Output IM level =	-11.62	dBm
Output IM level =	-25.62	dBC
SFDR =	51.64	dB

Figure A-1. System A Computed System Noise Figure, Gain, and Intermod Based on Reported Component Parameters (40 dB Spectrum Analyzer Attenuation).

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Stage Data	Units	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7
Stage Name:		Tunable BP filter	Miteq Preamp	Cable	Attenuator	Agilent Preamp	Cable	Agilent E4440
Noise Figure	dB	1	1	0	10	8	0	60
Gain	dB	-1	42	0	-10	25	0	0
Output IP3	dBm	100	19.6	100	100	27.6	100	62.6
dNF/dTemp	dB/°C	0	0	0	0	0	0	0
dG/dTemp	dB/°C	0	0	0	0	0	0	0
Stage Analysis:		0	0	0	0	0	0	0
NF (Temp corr)	dB	1.00	1.00	0.00	10.00	8.00	0.00	60.00
Gain (Temp corr)	dB	-1.00	42.00	0.00	-10.00	25.00	0.00	0.00
Input Power	dBm	-45.00	-46.00	-4.00	-4.00	-14.00	11.00	11.00
Output Power	dBm	-46.00	-4.00	-4.00	-14.00	11.00	11.00	11.00
d NF/d NF	dB/dB	0.33	0.41	0.00	0.00	0.00	0.00	0.64
d NF/d Gain	dB/dB	-0.67	-0.59	-0.59	-0.59	-0.58	-0.58	0.00
d IP3/d IP3	dBm/dBm	0.00	0.15	0.00	0.00	0.82	0.00	0.00

Enter System Parameters:

Input Power	-45	dBm
Analysis Temperature	25	°C
Noise BW	1	MHz
Ref Temperature	25	°C
S/N (for sensitivity)	0	dB
Noise Source (Ref)	290	°K

System Analysis:

Gain =	56.00	dB
Noise Figure =	6.13	dB
Noise Temp =	899.50	°K
SNR =	62.85	dB
MDS =	-107.85	dBm
Sensitivity =	-107.85	dBm
Noise Floor =	-167.85	dBm/Hz

Input IP3 =	-29.19	dBm
Output IP3 =	26.81	dBm
Input IM level =	-76.62	dBm
Input IM level =	-31.62	dBC
Output IM level =	-20.62	dBm
Output IM level =	-31.62	dBC
SFDR =	52.44	dB

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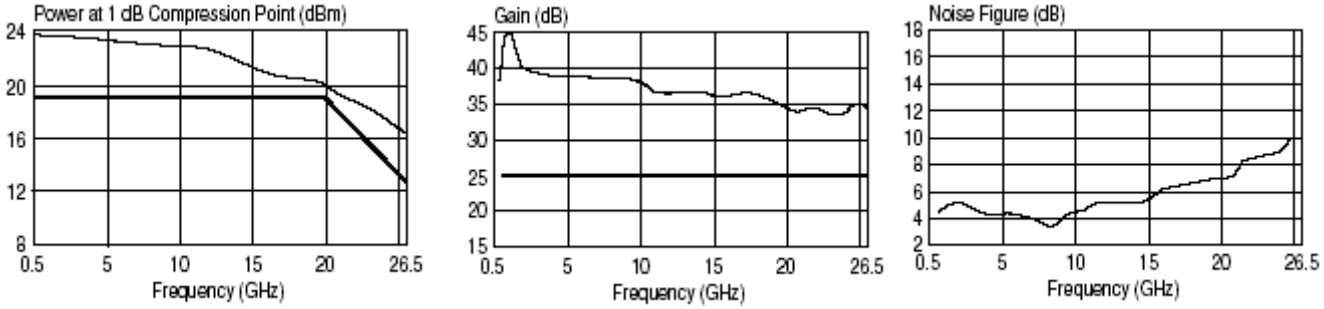
Figure A-2. System B Computed System Noise Figure, Gain, and IP3 Based on Reported Component Parameters (40 dB Spectrum Analyzer Attenuation).

Agilent 83017A performance parameters (from the Agilent 83000 Series data sheet):



The difference in gain between the reported component values and the calibration measurement are divided between the first LNA and the Agilent 83017A, with most of the difference assigned to the Agilent amplifier based on its gain variability. Typical data for the AFS series amplifiers from Miteq show that the minimum gain specification is indeed the minimum realized across the rated band and that the gain variation is ±1 dB. Likewise the typical data for the AMF series shows a small variation in gain.

AppCAD - [NoiseCalc]

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Stage Data	Units	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7
Stage Name:		Tunable BP filter	Miteq Preamp	Cable	Attenuator	Agilent Preamp	Cable	Agilent E4440
Noise Figure	dB	1	.6	0	10	5	0	60
Gain	dB	-1	45	0	-10	30.8	0	0
Output IP3	dBm	100	19.6	100	100	27.6	100	62.6
dNF/dTemp	dB/°C	0	0	0	0	0	0	0
dG/dTemp	dB/°C	0	0	0	0	0	0	0
Stage Analysis:		0	0	0	0	0	0	0
NF (Temp corr)	dB	1.00	0.60	0.00	10.00	5.00	0.00	60.00
Gain (Temp corr)	dB	-1.00	45.00	0.00	-10.00	30.80	0.00	0.00
Input Power	dBm	-45.00	-46.00	-1.00	-1.00	-11.00	19.80	19.80
Output Power	dBm	-46.00	-1.00	-1.00	-11.00	19.80	19.80	19.80
d NF/d NF	dB/dB	0.73	0.83	0.00	0.00	0.00	0.00	0.20
d NF/d Gain	dB/dB	-0.27	-0.17	-0.17	-0.17	-0.17	-0.17	0.00
d IP3/d IP3	dBm/dBm	0.00	0.04	0.00	0.00	0.94	0.00	0.00

Enter System Parameters:

Input Power	-45	dBm
Analysis Temperature	25	°C
Noise BW	1	MHz
Ref Temperature	25	°C
S/N (for sensitivity)	0	dB
Noise Source (Ref)	290	°K

System Analysis:

Gain =	64.80	dB
Noise Figure =	2.50	dB
Noise Temp =	225.56	°K
SNR =	66.48	dB
MDS =	-111.48	dBm
Sensitivity =	-111.48	dBm
Noise Floor =	-171.48	dBm/Hz

Input IP3 =	-37.42	dBm
Output IP3 =	27.38	dBm
Input IM level =	-60.15	dBm
Input IM level =	-15.15	dBC
Output IM level =	4.65	dBm
Output IM level =	-15.15	dBC
SFDR =	49.37	dB

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Figure A-3. System A Computed System Noise Figure, Gain, and IP3 Based on Component Parameters Inferred from the Reported Calibration (40 dB Spectrum Analyzer Attenuation).

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Stage Data	Units	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7
Stage Name:		Tunable BP filter	Miteq Preamp	Cable	Attenuator	Agilent Preamp	Cable	Agilent E4440
Noise Figure	dB	1	1	0	10	5	0	60
Gain	dB	-1	43.7	0	-10	30.8	0	0
Output IP3	dBm	100	19.6	100	100	27.6	100	62.6
dNF/dTemp	dB/°C	0	0	0	0	0	0	0
dG/dTemp	dB/°C	0	0	0	0	0	0	0
Stage Analysis:		0	0	0	0	0	0	0
NF (Temp corr)	dB	1.00	1.00	0.00	10.00	5.00	0.00	60.00
Gain (Temp corr)	dB	-1.00	43.70	0.00	-10.00	30.80	0.00	0.00
Input Power	dBm	-45.00	-46.00	-2.30	-2.30	-12.30	18.50	18.50
Output Power	dBm	-46.00	-2.30	-2.30	-12.30	18.50	18.50	18.50
d NF/d NF	dB/dB	0.65	0.80	0.00	0.00	0.00	0.00	0.24
d NF/d Gain	dB/dB	-0.35	-0.20	-0.20	-0.20	-0.20	-0.20	0.00
d IP3/d IP3	dBm/dBm	0.00	0.04	0.00	0.00	0.94	0.00	0.00

Enter System Parameters:

Input Power	-45	dBm
Analysis Temperature	25	°C
Noise BW	1	MHz
Ref Temperature	25	°C
S/N (for sensitivity)	0	dB
Noise Source (Ref)	290	°K

System Analysis:

Gain =	63.50	dB
Noise Figure =	3.08	dB
Noise Temp =	299.63	°K
SNR =	65.89	dB
MDS =	-110.89	dBm
Sensitivity =	-110.89	dBm
Noise Floor =	-170.89	dBm/Hz

Input IP3 =	-36.12	dBm
Output IP3 =	27.38	dBm
Input IM level =	-62.75	dBm
Input IM level =	-17.75	dBC
Output IM level =	0.75	dBm
Output IM level =	-17.75	dBC
SFDR =	49.85	dB

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Figure A-4. System B Computed System Noise Figure, Gain, and IP3 Based on Component Parameters Inferred from the Reported Calibration (40 dB Spectrum Analyzer Attenuation).

Table A-1. System A Estimated Noise Figure.

Frequency (MHz)	Noise Figure (dB)	Noise Floor in 1 MHz (dB)	Noise floor - antenna gain (dB)
1575.4	2.5	-111.5	-120.1
1227.6	2.2	-111.8	-119.0
1176	2.2	-111.8	-118.9
985	2.1	-111.9	-118.0
1035	2.1	-111.9	-118.3
1085	2.1	-111.9	-118.6
1135	2.2	-111.8	-118.7

Table A-2. System B Estimated Noise Figure.

Frequency (MHz)	Noise Figure (dB)	Noise Floor in 1 MHz (dB)	Noise floor - antenna gain (dB)
1575.4	3.1	-110.9	-119.5
1227.6	2.9	-111.1	-118.3
1176	2.8	-111.2	-118.3
985	2.5	-111.5	-117.6
1035	2.6	-111.4	-117.8
1085	2.6	-111.4	-118.1
1135	2.6	-111.4	-118.3